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Thomas

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(45) **Date of Patent: Jul. 12, 2016**

(54) **GREEN SWITCHGEAR APPARATUSES, METHODS AND SYSTEMS**

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(72) Inventor: **Rajesh Thomas**, Capalaba (AU)

(73) Assignee: **Schneider Electric Industries SAS**, Rueil-Malmaison (FR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 4 days.

(21) Appl. No.: **14/340,472**

(22) Filed: **Jul. 24, 2014**

(65) **Prior Publication Data**

US 2015/0027988 A1 Jan. 29, 2015

Related U.S. Application Data

(60) Provisional application No. 61/857,926, filed on Jul. 24, 2013, provisional application No. 62/027,169, filed on Jul. 21, 2014.

(51) **Int. Cl.**
H01H 33/664 (2006.01)
H01H 33/12 (2006.01)

(52) **U.S. Cl.**
CPC ***H01H 33/664*** (2013.01); ***H01H 33/122*** (2013.01); *H01H 2033/6648* (2013.01)

(58) **Field of Classification Search**
CPC . H01H 33/53; H01H 33/56; H01H 2033/566; H01H 2033/6623; H01H 2033/66223; H01H 2033/6648; H01H 33/122
USPC 218/117, 118, 134, 139, 155, 153, 154; 361/326, 605, 612
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,735,019 A * 5/1973 Hess .... H01B 17/32 174/14 BH
3,898,406 A * 8/1975 Larkin H01B 17/005 218/134
5,387,772 A * 2/1995 Bestel H01H 33/66207 218/118
5,808,258 A * 9/1998 Luzzi H01H 33/66207 218/136
5,917,167 A * 6/1999 Bestel B29C 63/18 218/138
7,473,863 B2 * 1/2009 Schreiber H01H 33/027 218/138
2010/0170774 A1 * 7/2010 Einschenk .... H01H 33/027 200/48 R

* cited by examiner

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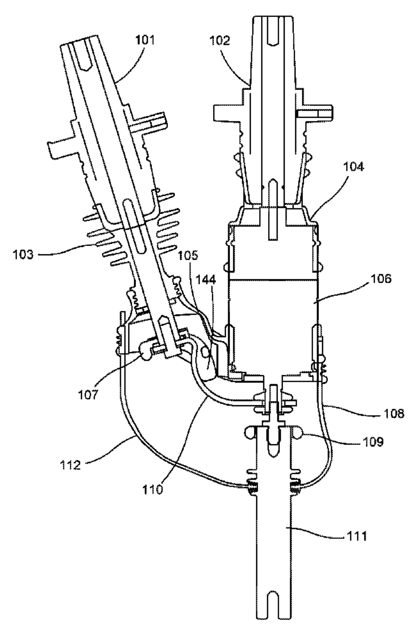
(57) **ABSTRACT**

This disclosure relates to switchgear equipment for electrical power systems. A switchgear comprises a switchgear body housing, having an upper boot and a lower boot, the upper boot having an insulating material and the lower boot having an insulating material, a vacuum interrupter having at least one stationary electrical contact, a moveable contactor coupled to a moveable electrical contact, and at least two bushings having conductor material passing therethrough, the switchgear further comprising at least one of a bushing boot having at least one of a helical groove and an array of heat-removal fins, a flexible, insulating cover enclosing at least a portion of the vacuum interrupter and an adjacent bushing, a helical groove in the upper boot, and a finned connector constrained within a channel in the moveable contactor.

18 Claims, 19 Drawing Sheets



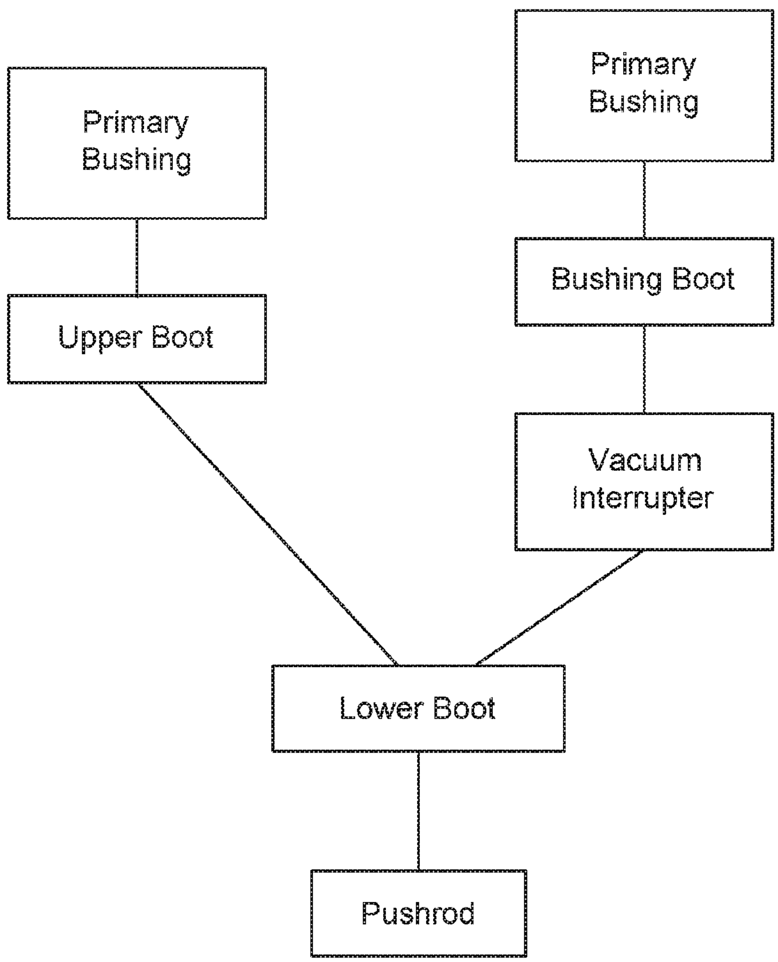

Primary
Bushing
Upper Boot
Primary
Bushing
Bushing Boot
Vacuum
Interrupter
Lower Boot
Pushrod

FIG. 1A

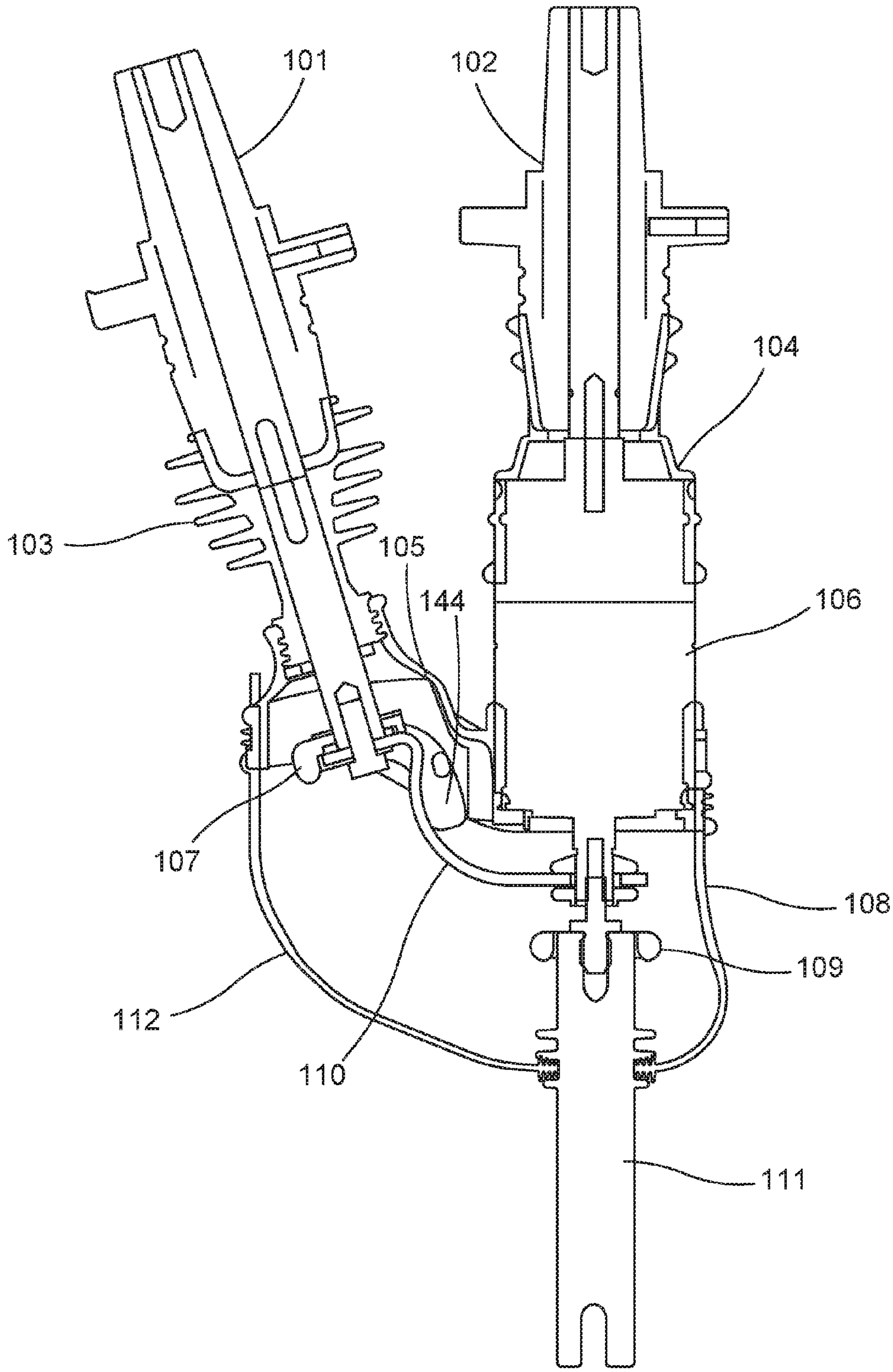


FIG. 1B

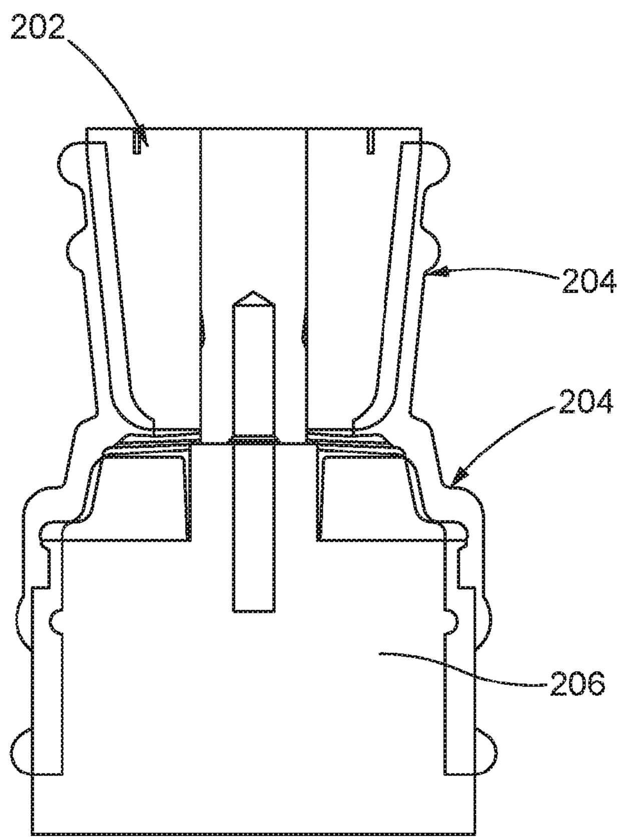


FIG. 2

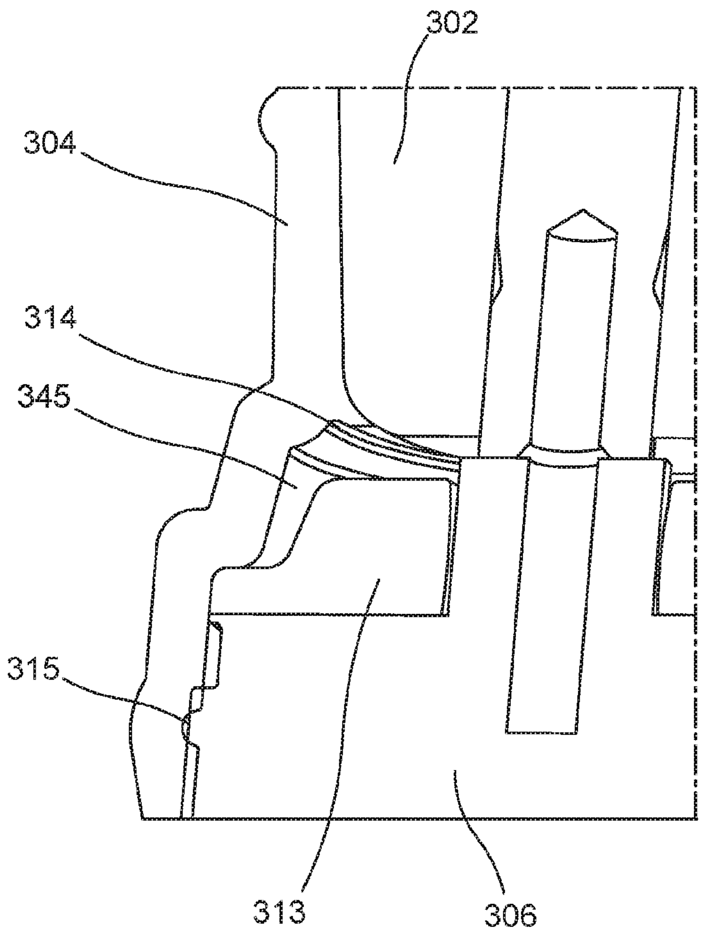


FIG. 3

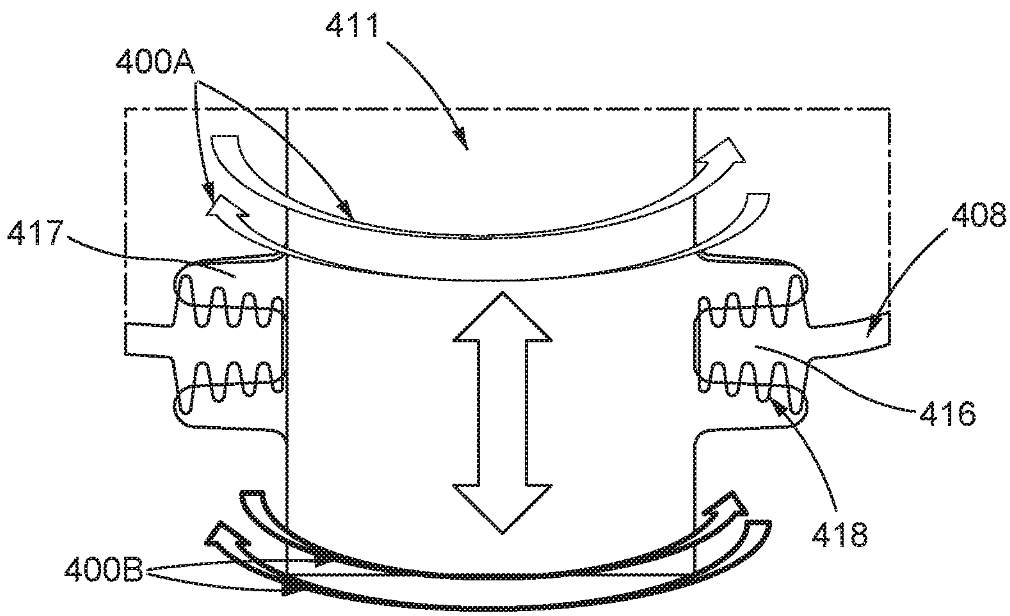


FIG. 4

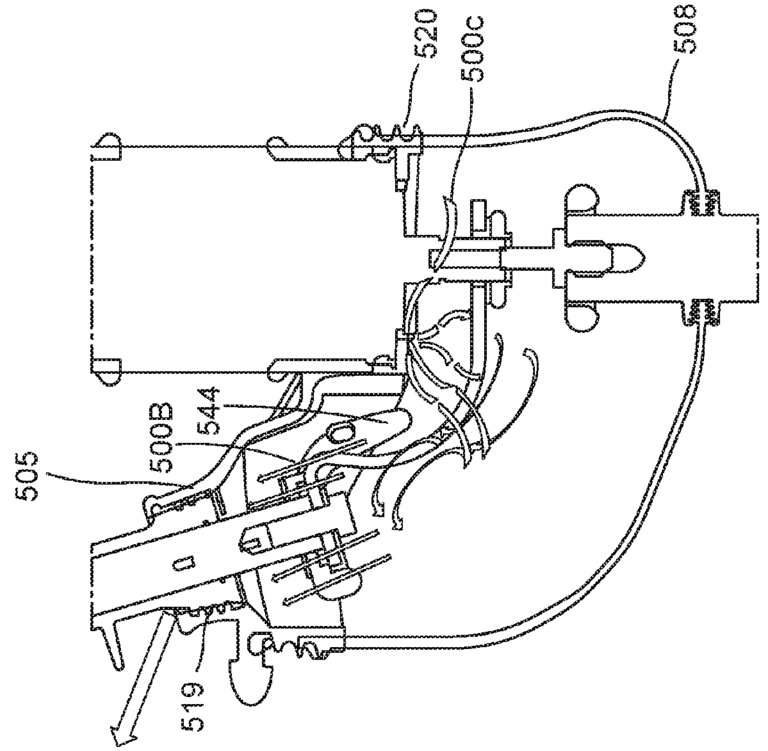


FIG. 5A

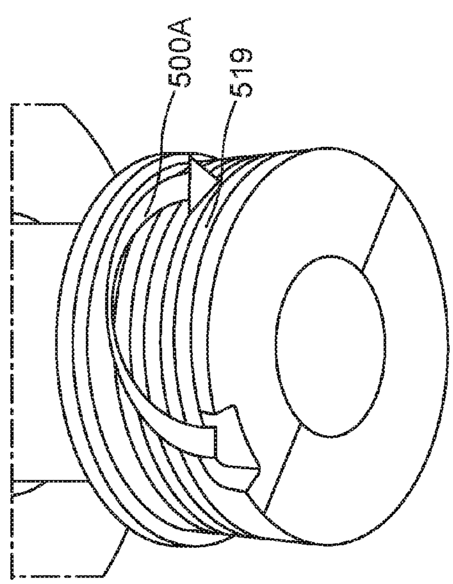


FIG. 5B

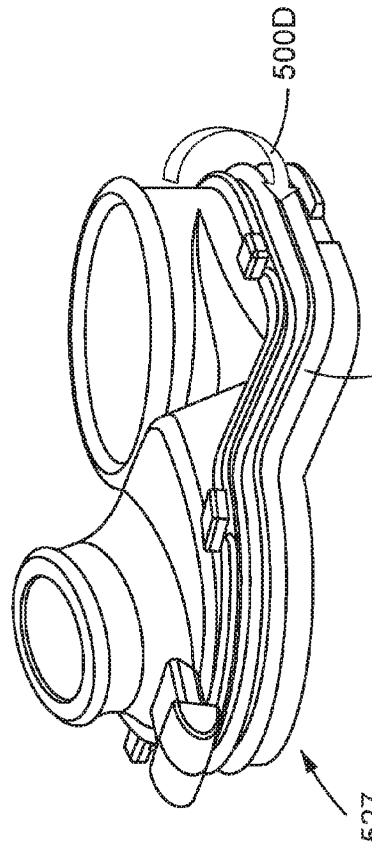


FIG. 5C

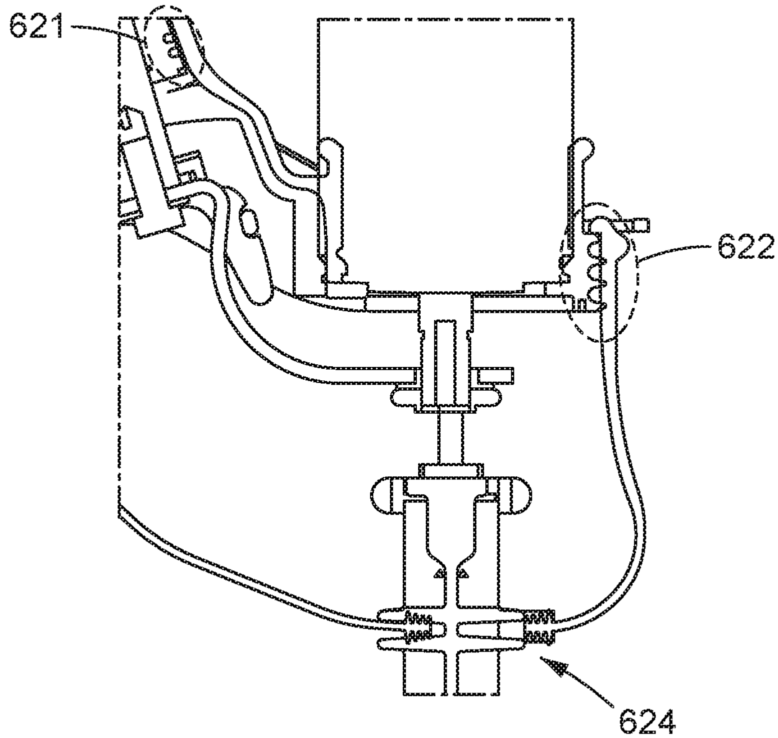


FIG. 6

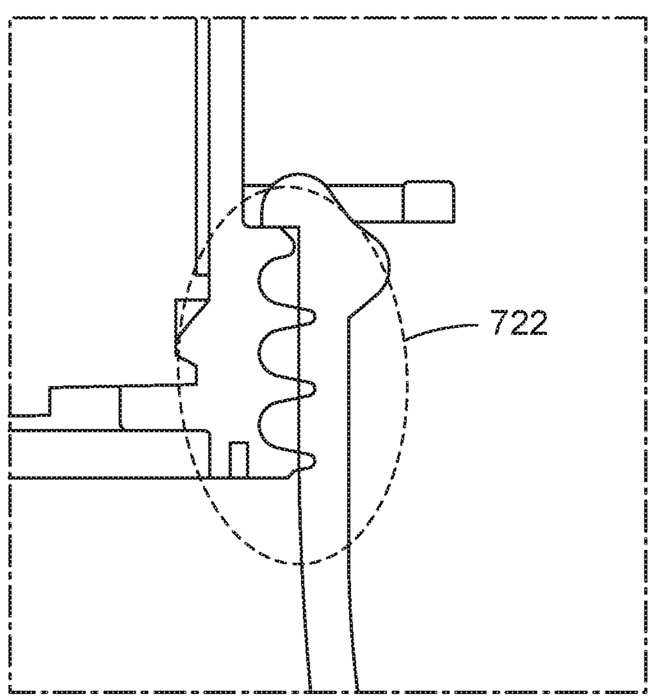


FIG. 7

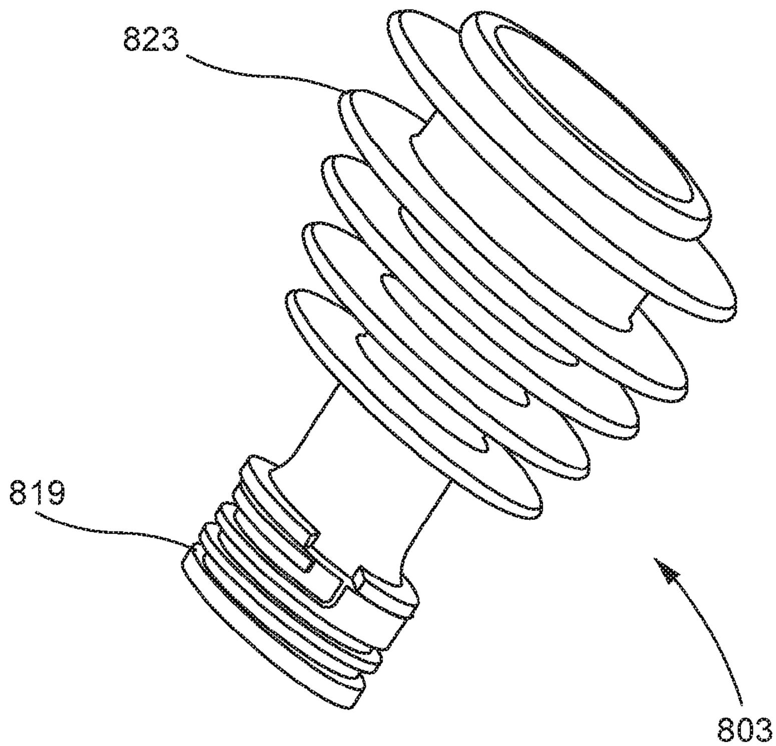


FIG. 8

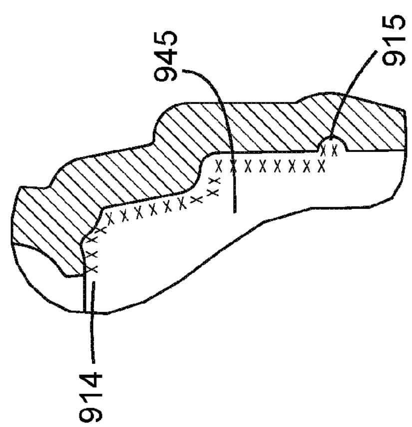


FIG. 9C

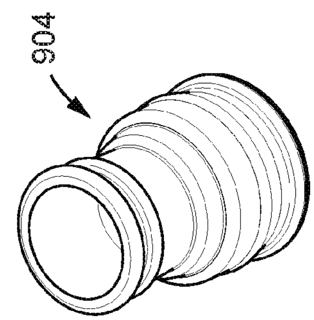


FIG. 9D

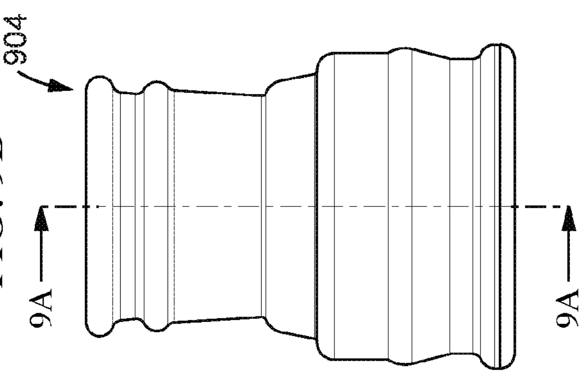


FIG. 9B

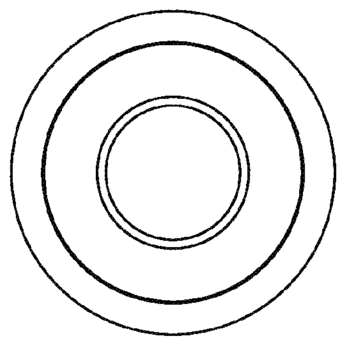


FIG. 9E

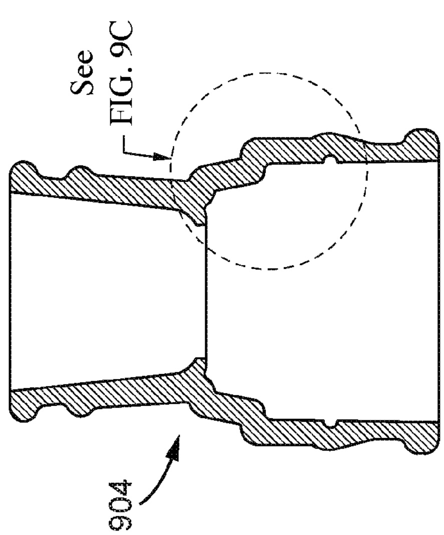


FIG. 9A

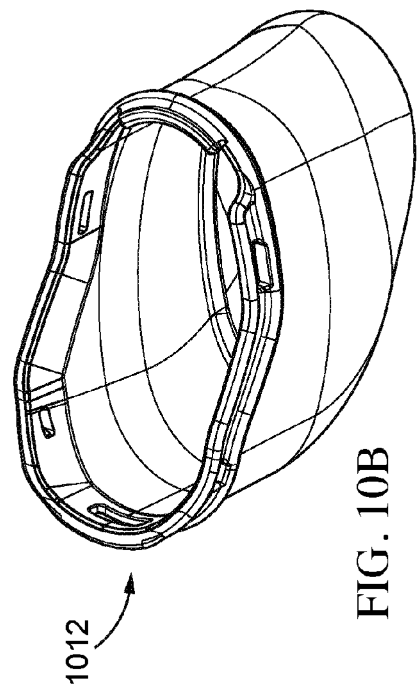


FIG. 10B

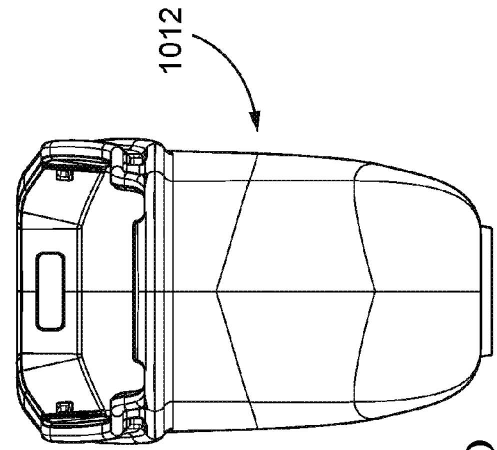


FIG. 10D

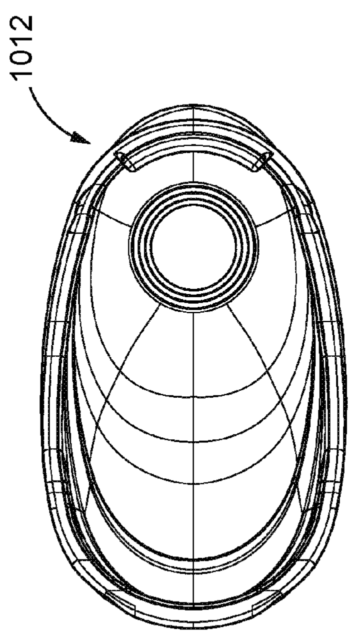


FIG. 10A

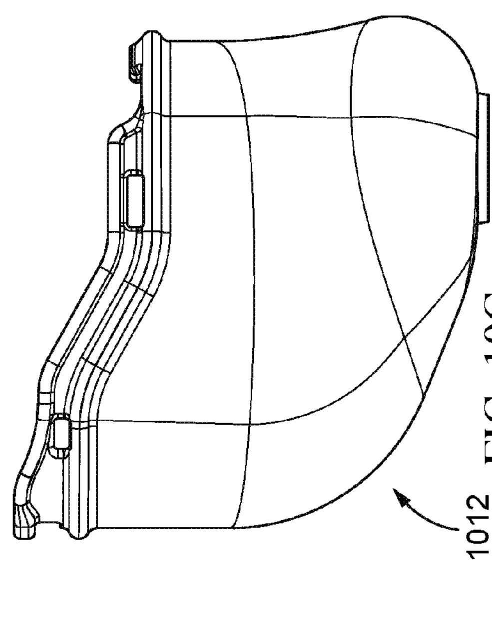


FIG. 10C

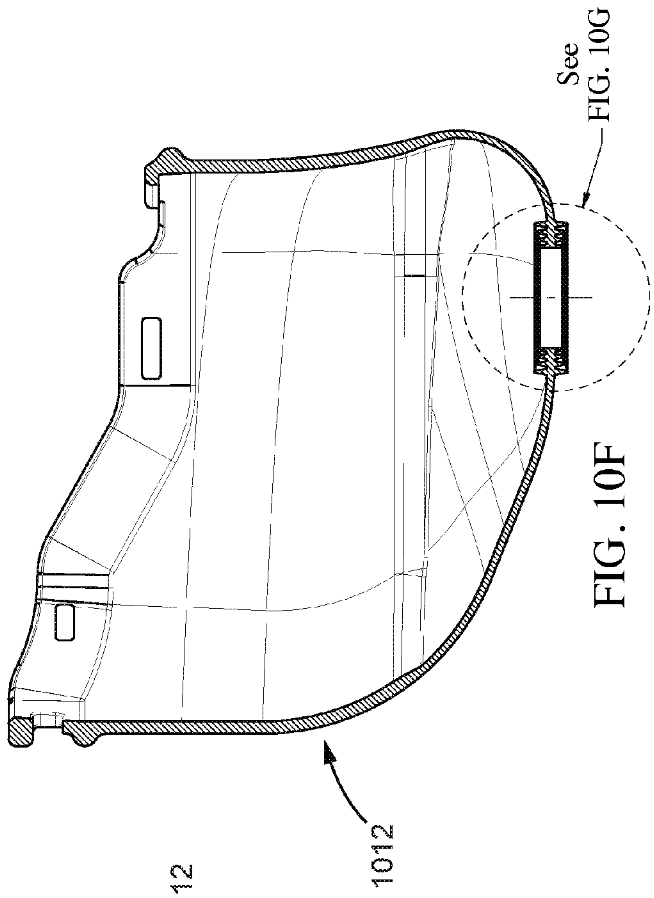
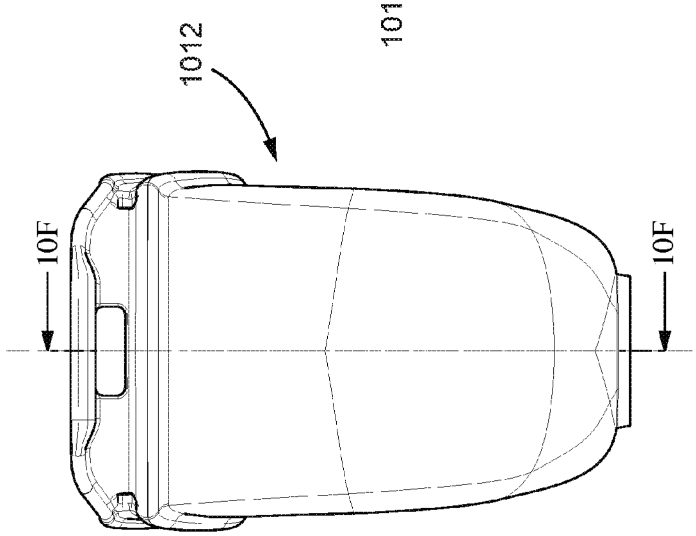


FIG. 10F



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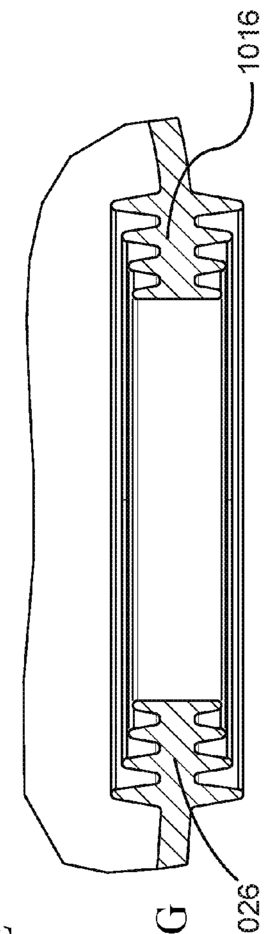

FIG. 10G

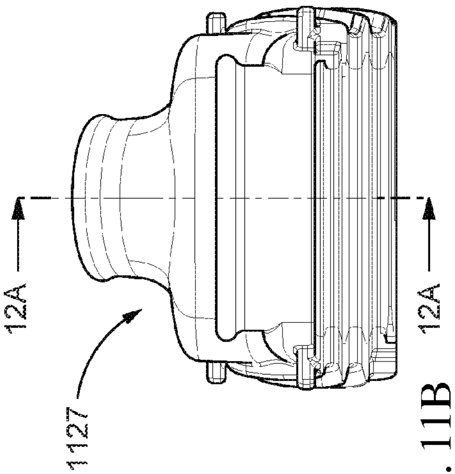

FIG. 11B

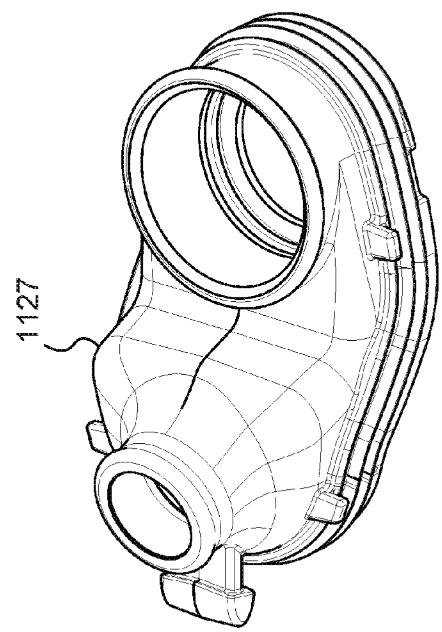

FIG. 11C

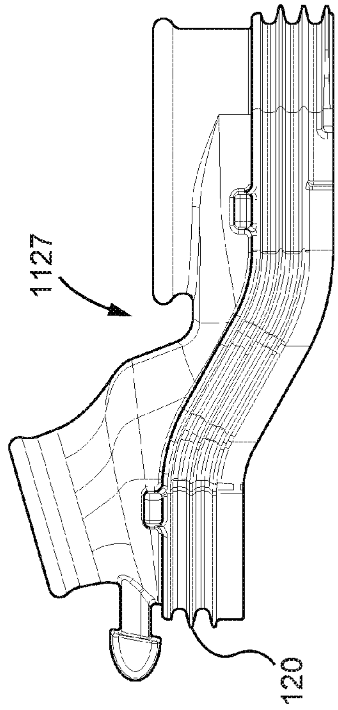

FIG. 11A

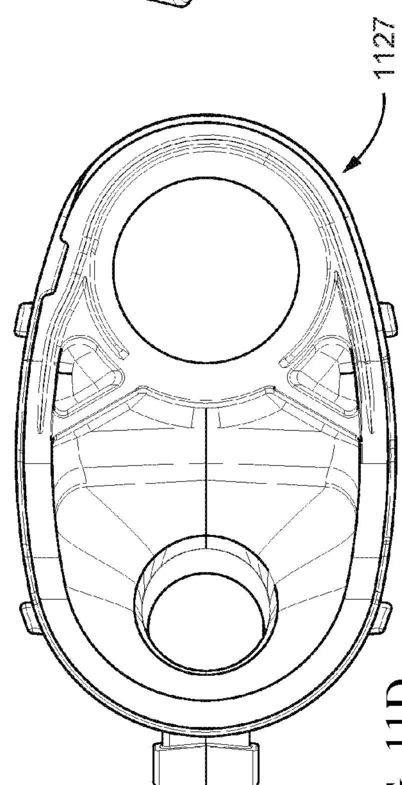

FIG. 11D

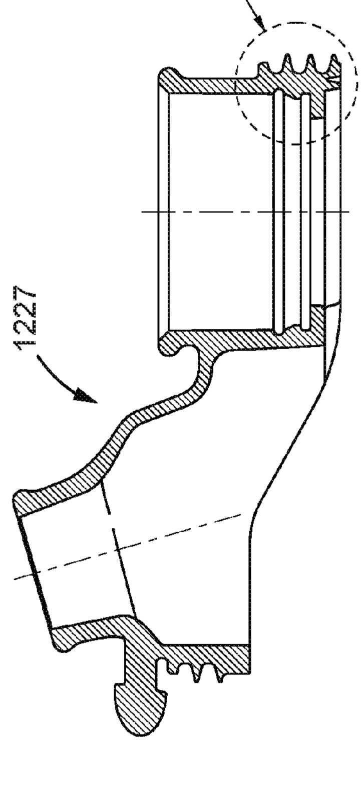

FIG. 12A

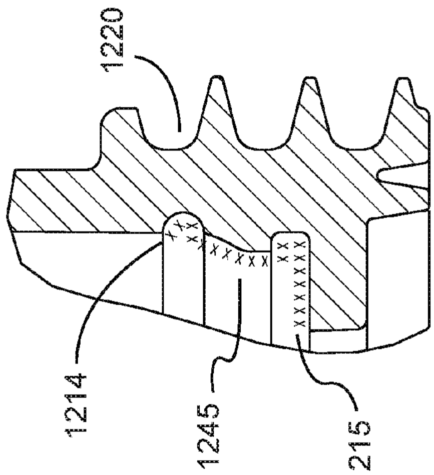

FIG. 12B

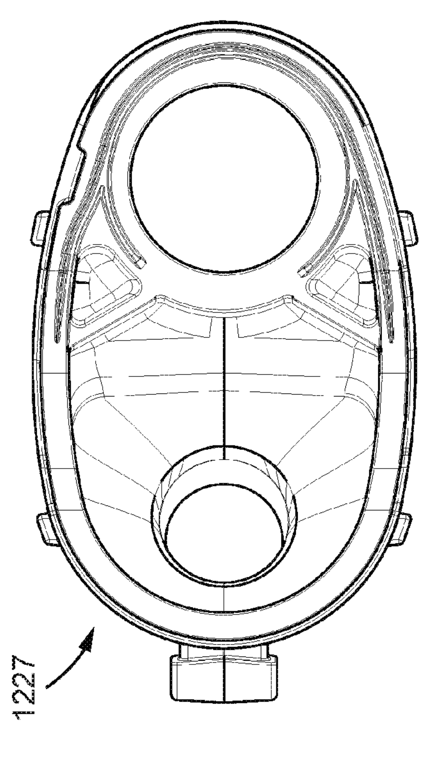

FIG. 12C

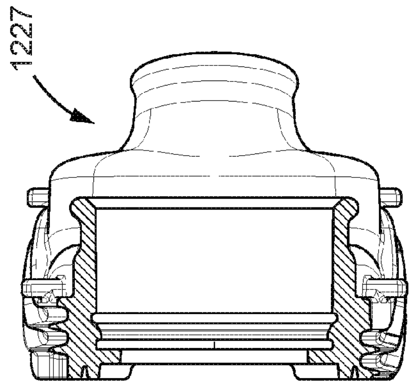

FIG. 12D

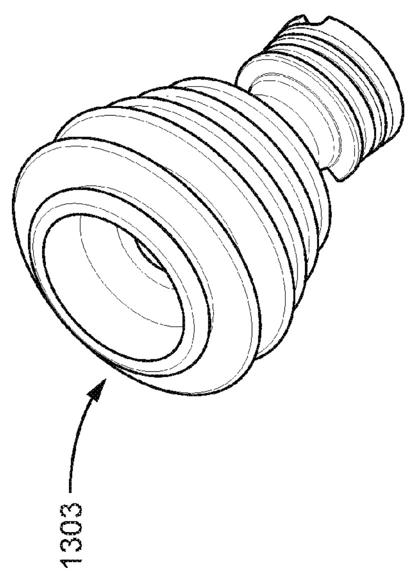

FIG. 13E

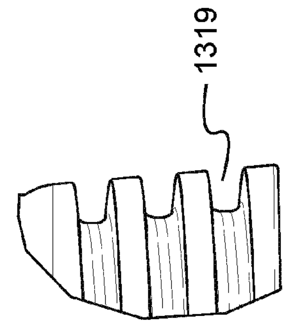

FIG. 13D

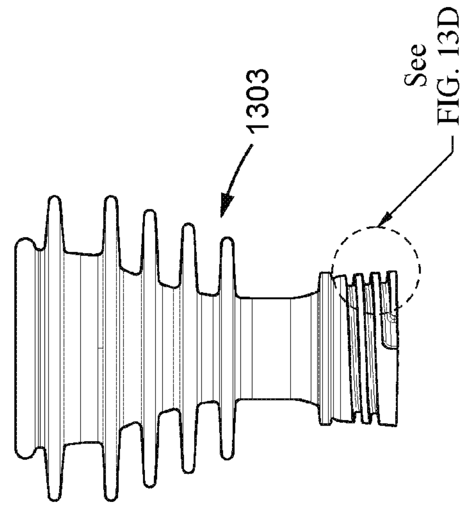

FIG. 13C

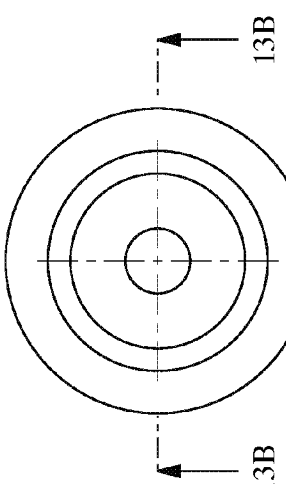

FIG. 13A

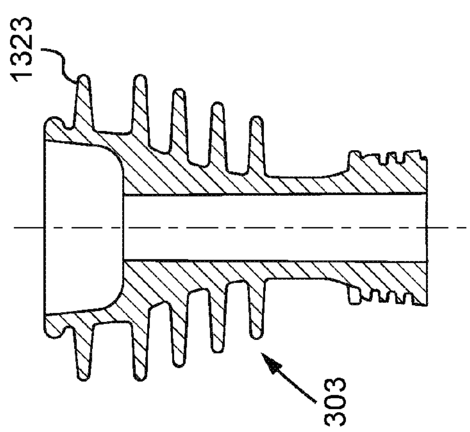

FIG. 13B

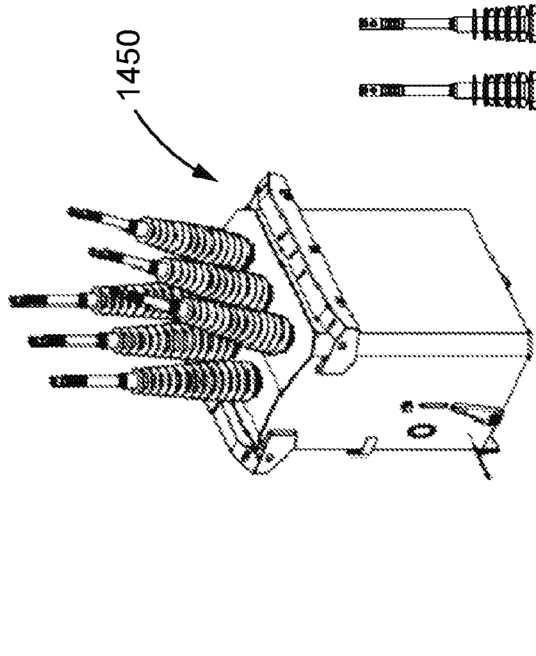

FIG. 14A

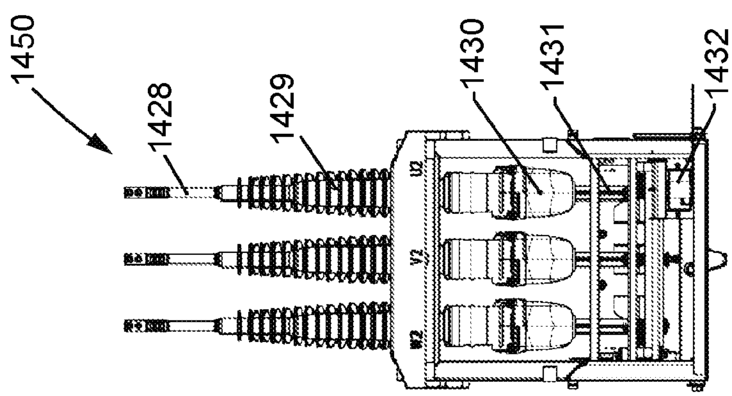

FIG. 14B

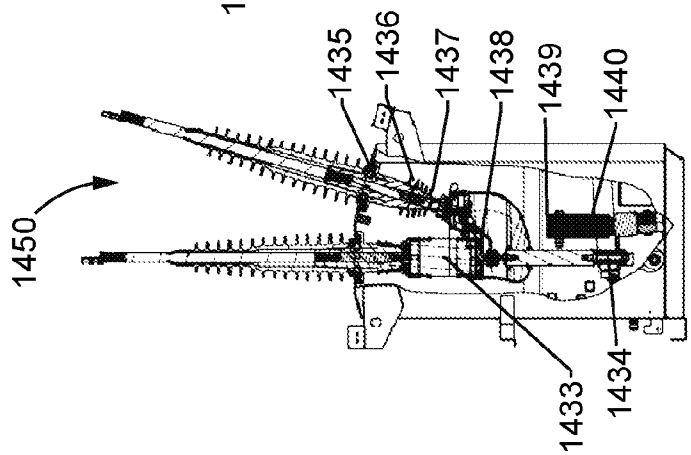

FIG. 14C

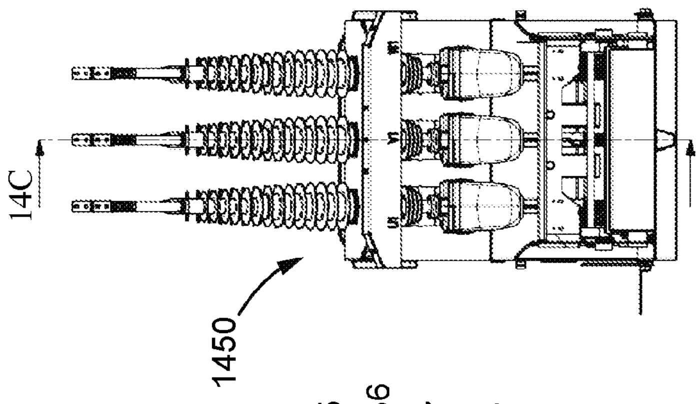

FIG. 14D

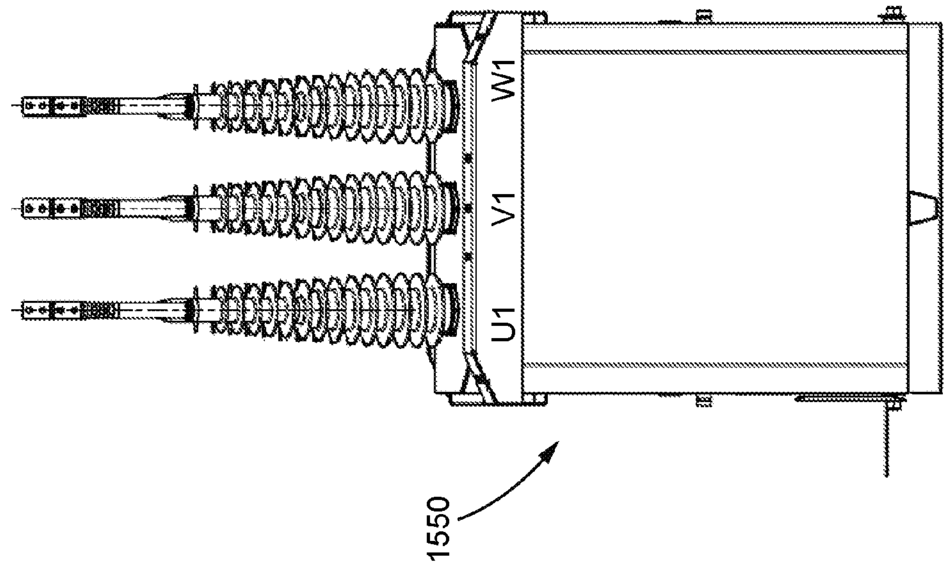

FIG. 15B

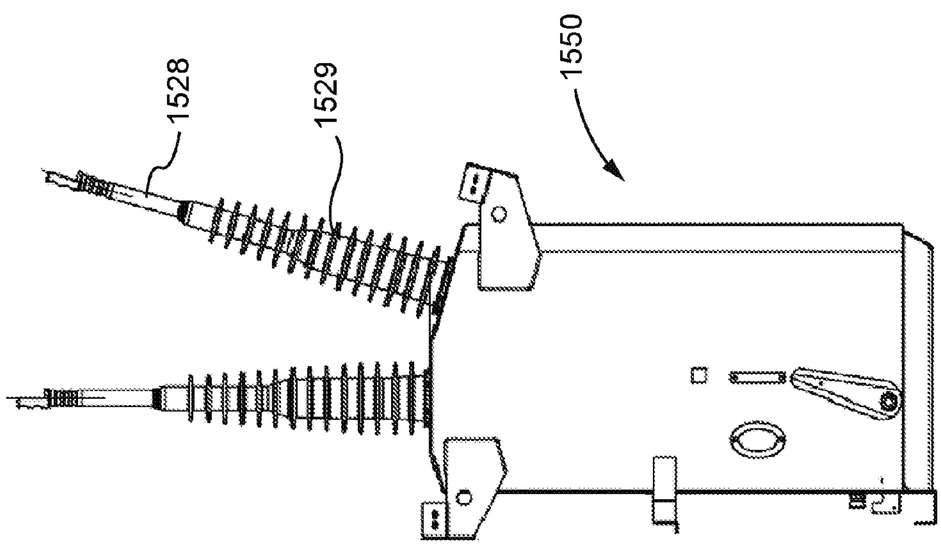

FIG. 15A

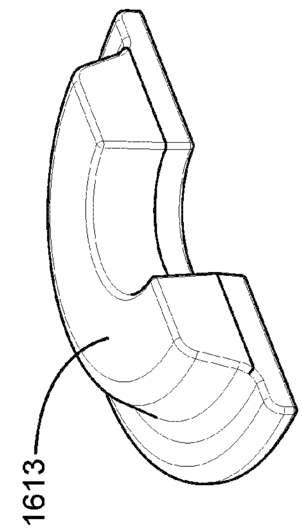

FIG. 16B

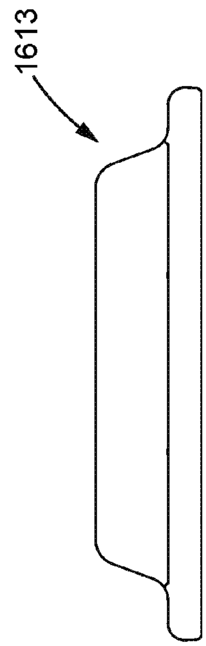

FIG. 16D

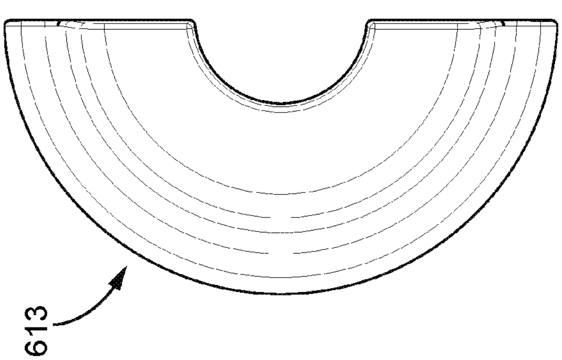

FIG. 16A

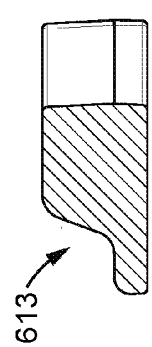

FIG. 16C

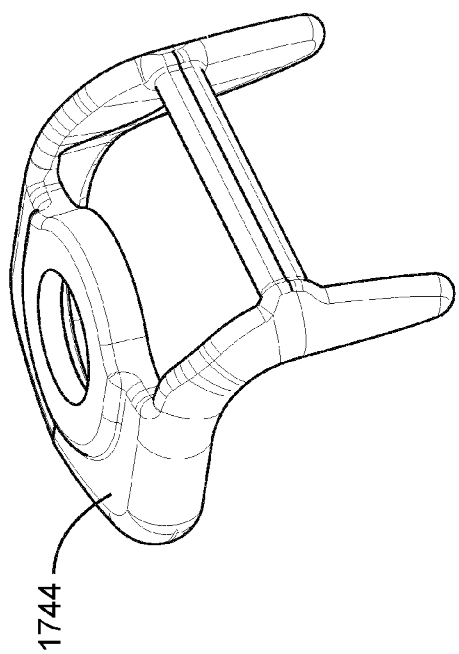

FIG. 17B

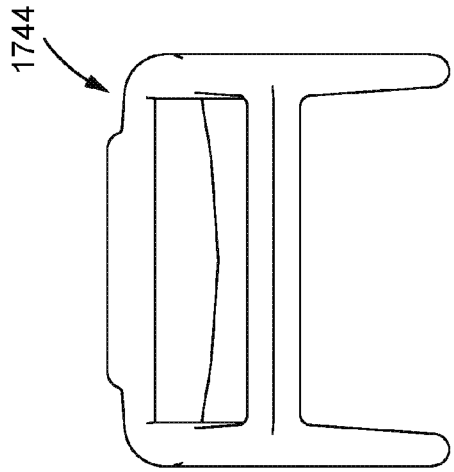

FIG. 17D

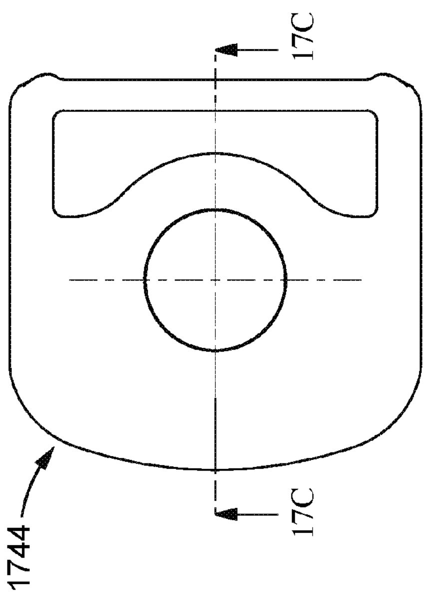

FIG. 17A

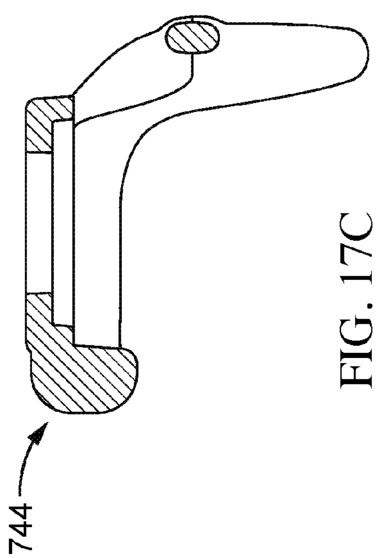

FIG. 17C

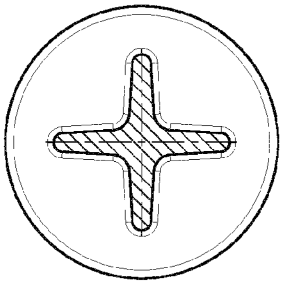

FIG. 18B

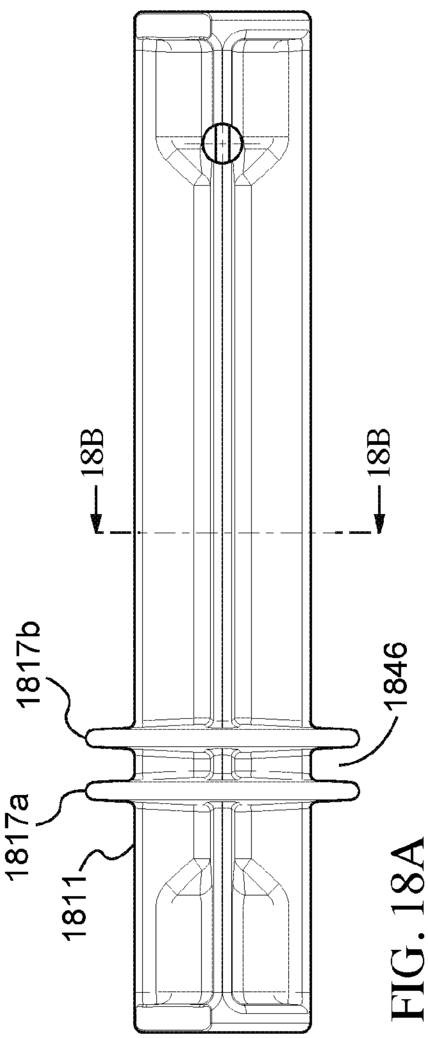

FIG. 18A

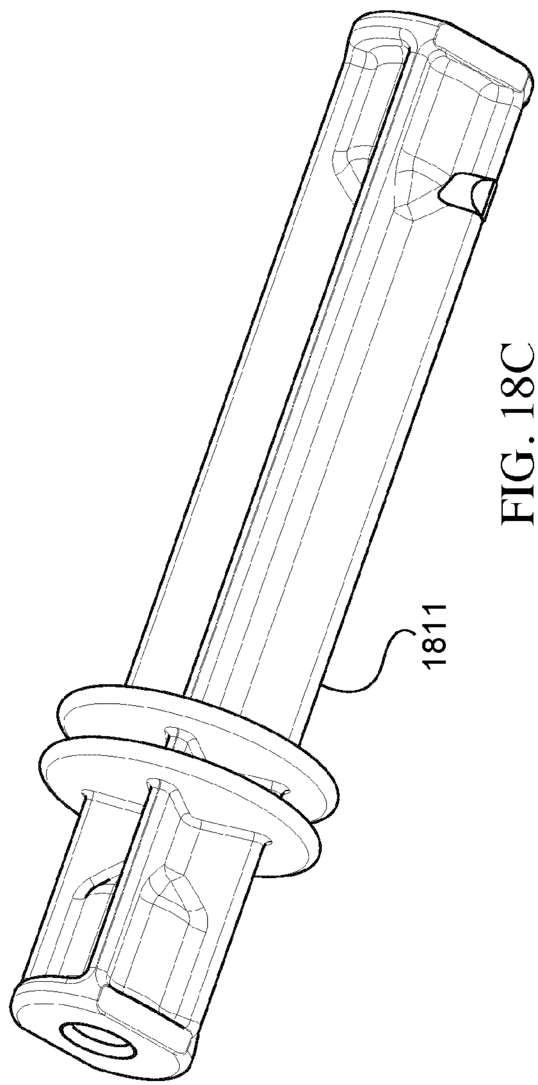

FIG. 18C

GREEN SWITCHGEAR APPARATUSES, METHODS AND SYSTEMS

This application claims the benefit of U.S. Provisional Application No. 61/857,926, filed Jul. 24, 2013, and of U.S. Provisional Application No. 62/027,169, filed Jul. 21, 2014. The entire contents of the aforementioned applications are herein expressly incorporated by reference.

This application also cross-references Australian Patent Application No. 2014206176, filed Jul. 24, 2014, the entire contents of which is herein expressly incorporated by reference.

FIELD

This disclosure is related to aspects of electric power delivery systems including, but not limited to, switchgear technology, and more particularly, GREEN SWITCHGEAR Apparatuses, Methods and Systems.

BACKGROUND

In electric power generation and distribution, switches, fuses, and circuit breakers are used to control power and protect connected equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

Embodiments of the GREEN SWITCHGEAR Apparatuses, Methods and Systems ("GREEN SWITCHGEAR") will now be described, by way of illustrative example only, with reference to the accompanying drawings, in which:

FIG. **1**A is a block diagram of an example embodiment of the GREEN SWITCHGEAR;

FIG. **1**B is a cross-sectional view of an example embodiment of the GREEN SWITCHGEAR;

FIG. **2** is a partial, cross-sectional detail view of a primary bushing (with a flexible insulator installed) according to some embodiments of the GREEN SWITCHGEAR;

FIG. **3** is a further partial, cross-sectional detail view of a primary bushing according to some embodiments of the GREEN SWITCHGEAR;

FIG. **4** is a cross-sectional detail view of a pushrod according to some embodiments of the GREEN SWITCHGEAR;

FIG. **5**A is a cross-sectional partial view of a switchgear (with dark and light arrows to represent exemplary hot and cold air flows, respectively), according to some embodiments of the GREEN SWITCHGEAR;

FIG. **5**B is a detail three-dimensionally rendered perspective view of a lower portion of the bushing boot of FIG. **5**A, according to some embodiments of the GREEN SWITCHGEAR;

FIG. **5**C is a three-dimensional rendering of the upper boot of FIG. **5**A, according to some embodiments of the GREEN SWITCHGEAR;

FIG. **6** is a cross-sectional partial view of a switchgear according to an embodiment of the GREEN SWITCHGEAR, indicating regions of helical grooves, and with one interphase seal not made, for example illustrating the assembled position of joint **622**;

FIG. **7** is a cross-sectional partial view of an embodiment of the GREEN SWITCHGEAR, indicating a region of helical grooves;

FIG. **8** is a three-dimensional rendering of a bushing boot according to some embodiments of the GREEN SWITCHGEAR;

FIG. **9**A is a schematic cross-sectional side view of a bushing boot according to some embodiments of the GREEN SWITCHGEAR;

FIG. **9**B is a schematic drawing of a side view of the bushing boot of FIG. **9**A;

FIG. **9**C is a cross-sectional detail view of a portion of the bushing boot of FIG. **9**A, depicting a region of conductive paint applied to an inner surface thereof;

FIG. **9**D is a schematic perspective view of the bushing boot of FIG. **9**A;

FIG. **9**E is a top view of the bushing boot of FIG. **9**A;

FIG. **10**A is a schematic top view of a lower boot according to some embodiments of the GREEN SWITCHGEAR;

FIG. **10**B is a perspective view of the lower boot of FIG. **10**A;

FIG. **10**C is a left side view of the lower boot of FIG. **10**A;

FIG. **10**D is a rear view of the lower boot of FIG. **10**A;

FIG. **10**E is a front view of the lower boot of FIG. **10**A;

FIG. **10**F is a left side cross-sectional view of the lower boot of FIG. **10**A, including an illustration of the inter-phase sealing mechanism;

FIG. **10**G is a detail view of the inter-phase sealing mechanism of the lower boot of FIG. **10**A;

FIG. **11**A is a left side view of an upper boot according to some embodiments of the GREEN SWITCHGEAR;

FIG. **11**B is a rear view of the upper boot of FIG. **11**A;

FIG. **11**C is a top perspective view of the upper boot of FIG. **11**A;

FIG. **11**D is a top view of the upper boot of FIG. **11**A;

FIG. **12**A is a cross-sectional view of an upper boot according to some embodiments of the GREEN SWITCHGEAR;

FIG. **12**B is a cross-sectional detail view of a portion of the upper boot of FIG. **12**A and depicting a region of conductive paint applied to an inner surface thereof;

FIG. **12**C is a top view of the upper boot of FIG. **12**A;

FIG. **12**D is a rear view of the upper boot of FIG. **12**A;

FIG. **13**A is a top view of a bushing boot according to some embodiments of the GREEN SWITCHGEAR;

FIG. **13**B is a cross-sectional side view of the bushing boot of FIG. **13**A;

FIG. **13**C is a side view of the bushing boot of FIG. **13**A;

FIG. **13**D is a detail side view of a portion of the bushing boot of FIG. **13**A;

FIG. **13**E is a perspective view of the bushing boot of FIG. **13**A;

FIG. **14**A is a perspective view of a switchgear according to an embodiment of the GREEN SWITCHGEAR;

FIG. **14**B is a cross-sectional rear view of the switchgear of FIG. **14**A;

FIG. **14**C is a cross-sectional left view of the switchgear of FIG. **14**A;

FIG. **14**D is a cross-sectional front view of the switchgear of FIG. **14**A;

FIG. **15**A is a left view of a switchgear according to an embodiment of the GREEN SWITCHGEAR;

FIG. **15**B is a front view of the switchgear of FIG. **15**A;

FIG. **16**A is a partial top view of a spacer according to some embodiments of the GREEN SWITCHGEAR;

FIG. **16**B is a perspective partial view of the spacer of FIG. **16**A;

FIG. **16**C is a partial radial cross-section view of the spacer of FIG. **16**A;

FIG. **16**D is a side view of the spacer of FIG. **16**A;

FIG. **17**A is a top view of a flexible guide according to some embodiments of the GREEN SWITCHGEAR;

FIG. **17**B is a perspective view of the flexible guide of FIG. **17**A;

FIG. **17**C is a cross-sectional view of the flexible guide of FIG. **17**A;

FIG. **17**D is a rear view of the flexible guide of FIG. **17**A;

FIG. **18**A is a side view of a pushrod according to some embodiments of the GREEN SWITCHGEAR;

FIG. **18**B is an end view of the pushrod of FIG. **18**A; and

FIG. **18**C is a perspective view of the pushrod of FIG. **18**A.

DETAILED DESCRIPTION

As disclosed herein, embodiments of the GREEN SWITCHGEAR Apparatuses, Methods and Systems ("GREEN SWITCHGEAR") provide innovative new advances in electric power distribution and management.

Sulfur hexafluoride (SF_6) is a chemically stable, electrically insulating gas used in high voltage switchgear equipment in electric power systems. SF_6 is also a greenhouse gas, and may produce lethal byproducts when subjected to arcing or corona discharge. Embodiments of the disclosed GREEN SWITCHGEAR provide innovative SF_6 replacement architecture, voltage sealing and heat transfer. Additional and/or alternative embodiments of the GREEN SWITCHGEAR provide for innovative voltage sealing and/or heat transfer.

As used herein, switchgear can include switches, fuses, circuit breakers, substations, fault isolation equipment, arc prevention equipment, other types of electrical isolation equipment, combinations thereof, and/or the like, and can be employed for low, medium, and/or high-voltage applications. Switchgear can be insulated using oil, vacuum, and/or gases, and/or the like. In some switchgear configurations, degraded performance, in some instances due to partial discharge, can occur, for example due to trapped air introduced by the placement of flexible insulators close to a voltage source, and/or the presence of sharp points, "burrs" or other asperities that can act as field concentration points, leading to electrical shorting and degraded performance. Also, industrial production and/or usage of switchgear insulated with sulfur hexafluoride (hereinafter "SF_6") can potentially lead to the release of SF_6 gas, a potent greenhouse gas, into the environment. Switchgear can be "voltage sealed" to insulate the primary current carrying path from earth potential for power-frequency and lightning impulse voltages. This is done by incorporating electrically-insulating elements (e.g., "basic insulation level," hereinafter "BIL"), which keep the high voltage insulated from earth. In some applications, voltage sealing in switchgear devices is accomplished either by employing insulators that are dimensioned such that the creepage distance is sufficient to withstand an applied voltage, or by employing a large diaphragm to seal the pushrod/epoxy body junction, the seal often having multiple types of insulating material, the majority of which is generally non-flexible epoxy. Creepage distance is defined as the shortest distance between two conductive parts—e.g., between two parts having different voltage values, or between a part having a high potential and a part at earth potential—as measured along the surface of what lies between them, e.g. one or more insulators. These methods of voltage sealing generally pertain to designs using a large clearance between conductive parts (i.e., creepage). Known air-insulated switchgear equipments, for example, are typically designed to have larger dimensions, due to BIL specifications and thermal management concerns (e.g., convection and the free movement of air/gas).

Some embodiments of the disclosure provide for the fabrication of switchgear equipment without the use of sulfur hexafluoride (hereinafter "SF_6") and/or switchgear equipment that does not include SF_6, via innovative designs incorporating dielectric materials such as silicone rubber and air. Depending on the embodiment, the GREEN SWITCHGEAR, according to the disclosure, may contain no SF_6, may be essentially free from SF_6, may be substantially free from SF_6, or may use less SF_6 than is typically used in known switchgear technology. Switchgear produced according to aspects of the present disclosure may be free from partial discharge, display desirable "withstand voltage" (i.e., dielectric breakdown voltage) and BIL levels, and satisfy industrial heat rise specifications without compromising the short-circuit performance. For example, in one embodiment described below with reference to the drawings, an elastic cover may be used to provide a "voltage seal" around a bushing (e.g., an epoxy resin-cast bushing, a porcelain bushing(s), and/or the like). The bushing is coupled to a vacuum interrupter, and the elastic cover insulates the conductor and avoids the negative impact of partial discharge caused by the application of silicone rubber or the presence of flexible insulators on or along the primary current carrying path. The use of a flexible insulating barrier may, in some contemplated embodiments, be used to cover the entirety of the current carrying part, for example enabling voltage sealing without causing partial discharge. In one embodiment, silicone rubber may be used to cover all current-carrying components of the switchgear.

Some embodiments of the GREEN SWITCHGEAR result in a reduction of overall switchgear size of at least 50%, as compared with known switchgear. In other words, the technology described by this disclosure allow for a reduction in size of switchgear, as compared with known switchgear, while retaining the same level of performance regarding one or more performance metrics (such as power rating, power consumption, arc withstand voltage, thermal management capability, etc.). For example, known air-insulated switchgear can have a width of 1200 mm, while switchgear according to the disclosed GREEN SWITCHGEAR can have a width of 600 mm or less. Depending on the embodiment, switchgear according to the disclosure may permit a reduction in overall switchgear size, as compared with known switchgear, of up to approximately 20%, up to approximately 25%, up to approximately 30%, up to approximately 40%, up to approximately 50%, between approximately 45% and approximately 55%, up to approximately 60%, up to approximately 70%, or up to approximately 80%. In some embodiments, switchgear according to the disclosure may permit a reduction in overall switchgear size of at least approximately 50%, at least approximately 65%, at least approximately 75%, or at least approximately 80%. Some embodiments of the GREEN SWITCHGEAR have a 50% smaller footprint for the same voltage rating, when compared with the footprint and voltage rating of a known switchgear, with minimum or no reduction in creepage distance required in air. Some embodiments of the GREEN SWITCHGEAR are SF_6-free and partial-discharge free, with similar temperature rise performance during maximum normal current when compared with known switchgear. Some embodiments of the GREEN SWITCHGEAR provide an improvement in temperature rise performance or "heat rise" performance when compared with known switchgear. For example, in some embodiments, a switchgear according to the disclosure exhibit an approximately 5° C., approximately 10° C., approximately 15° C. or approximately 20° C. improvement in temperature rise performance. Temperature rise performance may refer to the ability of the switchgear to sustain a specific level of performance at a higher temperature than a conventional switchgear would be capable of doing. Temperature rise performance may be described, for example, through a series of performance graphs (e.g., relating to power rating, voltage setting, load frequency, and/or other electrical parameter or performance measurement, and/or the like) each corresponding to a different ambient temperature condition (e.g., as ambient temperature increases, performance may degrade in one or more measurable ways).

Some embodiments of the GREEN SWITCHGEAR are SF_6-free and partial-discharge free, with similar temperature rise performance during maximum normal current when compared with known switchgear. Some embodiments of the GREEN SWITCHGEAR have a 10° C. improvement in temperature rise performance when compared with known air-insulated switchgear.

According to some embodiments of the GREEN SWITCHGEAR, a conductive coating is applied to surface(s) of at least one silicone rubber part which will then abut at least one "primary component" (e.g., a vacuum-interrupter and/or the like, typically of metal composition). This conductive coating can advantageously be applied such that the morphology of the coating surface, either by virtue of the paint itself or by virtue of the paint in combination with the underlying structure to which it is applied, has a non-abrupt (e.g., rounded, gently sloping, etc.) contour and/or shape. Said contour and/or shape may, for example, be macroscopically free from sharp points or edges. In some embodiments, the conductive coating is topographically "dull," i.e., the presence of sharp points, sharp edges, and/or other asperities has been reduced, minimized or eliminated. In an exemplary embodiment, a rounded conductive edge is provided at least along an end portion of the conductive coating that faces the lower potential (e.g., earth, ground, 0 volts, "reference potential," etc.). In a further embodiment, a rounded conductive edge is provided at least along two end portions of the conductive coating, one that is closest to the high voltage supply and one that is closest to the ground potential. The conductivity of the paint, shape of the painted profile, and/or location of the painted area can be configured to avoid partial discharge caused by trapped air at the mating surfaces on primary current carrying components, while the curved ends of the paint reduce unwanted partial electrical discharge caused by field concentration at sharp points and edges. In other contemplated embodiments, instead of or in addition to conductive paint, the silicone rubber (or other insulating material) elements of the GREEN SWITCHGEAR may comprise a conductive material (e.g., conductive powders, shavings, parts, etc.) embedded or otherwise incorporated therein.

Some embodiments of the disclosure relate to the interface between a switchgear body and a moving contactor part such as a pushrod. The moving contactor may be made at least partially of a suitable material such as polybutylene terephthalate (PBT), and/or other thermoplastic, polymer, and/or polyester materials, and/or various combinations thereof, and/or the like. The moving contactor may, in some embodiments, traverse a wall of the switchgear via a lower boot. For example, a finned connector comprising a flexible insulator such as silicone rubber may be provided in the switchgear body such that the finned connector may be at least partially received in a channel defined between solid insulating barriers on a pushrod. In some embodiments, the connector may snap into place. The pushrod channel may define a gap between said insulating barriers, which in some embodiments protrude from the surface of the pushrod. The fins of the finned connector can be configured and/or dimensioned such that they are received sufficiently tightly between the pushrod barriers so that, for example, a reliable seal may be made and retained during actuation of the pushrod. Such an embodiment may be said to provide an "inter-phase seal." In some embodiments, the inter-phase seal is positioned between a high voltage portion of the switchgear and a zero-potential portion of the switchgear.

In some embodiments, helical grooves (defined herein as continuous grooves that multiply traverse the periphery of a component, regardless of that component's shape) may be provided in at least one switchgear component to allow movement of gas (e.g., air) between a flexible barrier and the switchgear chamber. It is to be understood that helical grooves according to some embodiments of the disclosure can be defined as a continuous groove or grooves that multiply traverse the periphery of a component, regardless of the overall shape of the component. In some embodiments, a helical groove (or grooves) may appear to be generally, topologically, and/or substantially coiled, wound, corkscrew, spiral, screw shaped, radially-circling, helicoid, circumvoluted, and/or the like, based on the structure of the component. These helical grooves can be configured to improve voltage sealing by providing sufficient creepage distance to prevent flashover and/or voltage breakdown, and may also allow for the "breathing" (e.g., pressure release, removal of air/vacuum pockets, etc.) of confined areas such as the switchgear body, in addition to providing a path for thermal transfer between, for example, a switchgear chamber and a flexible insulating barrier and/or silicone rubber component and/or the like.

Further embodiments of the GREEN SWITCHGEAR incorporate silicone rubber (and/or like material) parts bearing multiple heat transfer fins, capable of transferring heat, for example by convection, radiation and/or conduction. In some such embodiments, the fins may be provided on a bushing boot that may further include helical grooves. A bushing boot, as described in greater detail below, may in some embodiments couple to a corresponding bushing and further function as a feedthrough, e.g., having a coaxial path through which a conductor may be inserted and/or serve as a "conduit."

FIG. **1**A is a system block diagram of a switchgear device according to the disclosed GREEN SWITCHGEAR. FIG. **1**B shows a cross-sectional view of a switchgear device according to an implementation of some embodiments of the GREEN SWITCHGEAR, having a lower boot **108** comprising silicone rubber, an upper boot **105** also comprising silicone rubber (the upper and lower boots together forming a main switchgear body **112**), a pushrod **111**, a vacuum interrupter **106** coupled to a first primary bushing **102** by bushing boot **104** and received by the switchgear body via upper boot **105**, a flexible guide **144**, a flexible conductor **110**, a flexible shroud **107**, a pushrod shroud **109**, and a second primary bushing **101** fitted to a finned silicone rubber bushing boot **103**, the bushing boot **104** also received by the switchgear body via the upper boot. The vacuum interrupter **106** can be directly coupled or indirectly coupled (e.g., by way of an intervening component such as a spacer, connector, wire, conductor element, etc.) to the first primary bushing **102**. Similarly, the vacuum interrupter **106** can be directly coupled or indirectly coupled (e.g., by way of an intervening component such as a spacer, connector, wire, conductor element, etc.) to the second primary bushing **101**. In some embodiments, more than two primary bushings may be used. In some embodiments, when more than two primary bushings are used, the vacuum interrupter can be directly coupled to each of the primary bushings. In other embodiments involving more than two primary bushings, the vacuum interrupter is indirectly coupled to each one of the primary bushings. In still other embodiments involving more than two primary bushings, the vacuum interrupter can be directly coupled to one or more of the primary bushings, and indirectly coupled to one or more of the remaining primary bushings.

As illustrated in greater detail in FIG. **2**, the interface between the vacuum interrupter **206** and a primary bushing **202** may be covered by or wrapped with an elastic insulating cover **204** comprising silicone rubber that extends partway along both the primary bushing **202** and the vacuum interrupter **206**. The vacuum interrupter **206** can be directly coupled or indirectly coupled (e.g., by way of an intervening component such as a spacer, connector, wire, conductor element, etc.) to the primary bushing. Although several components of the GREEN SWITCHGEAR are described throughout this disclosure as comprising silicone rubber, it is to be understood that other suitable materials having suitable insulating, elasticity, flexibility and/or other relevant material properties may also be used, whether in combination with, or as a substitute for, silicone rubber, for example ethylene propylene diene monomer (EPDM) rubber, natural rubber, viton, nitrile butadiene rubber (NBR), and/or the like. In some embodiments, it may be desirable to employ silicone grease at one or more interfaces of the GREEN SWITCHGEAR, for example as a protectant and/or lubricant. In some embodiments, silicone grease is applied to one or more "like" interfaces (e.g., between silicone rubber and silicone rubber).

FIG. **3** is a further detail cross-sectional view of a primary bushing according to some embodiments of the GREEN SWITCHGEAR, in which an aluminum spacer **313** is positioned between the vacuum interrupter **306** and its adjacent primary bushing **302**. FIG. **3** also depicts the interface (e.g., extending from location **314** down to location **315**) along which conductive paint (or other conductive coating) that has been applied to the interior of the silicone rubber cover **304** (in some embodiments referred to as a "bushing boot") contacts a circumferential portion of the aluminum spacer **313** (e.g., at **345**) as well as a portion of the vacuum interrupter **306** and a portion of bushing **302**. Conductive surfaces of the GREEN SWITCHGEAR can be advantageously shaped such that they do not contain any fine points or protruding edges (e.g., the surfaces are rounded or otherwise non-abrupt—see, e.g., the contour at **314**). As discussed above, the shape of the conductive surfaces may result from the shape of the underlying structure (e.g., the silicone rubber cover), or may result of the application of the paint (e.g., applying the paint with sufficient thickness and with appropriate care so as to allow a rounded 'fillet' of paint to dry in locations where a sharp edge or protrusion would otherwise have been exposed and/or imparted to the finish). In some embodiments, the method of applying the conductive layer(s) determines the conductive layer(s)'s topography. For example, metal films deposited using vacuum deposition techniques (including but not limited to physical vapor deposition, chemical vapor deposition, thermal evaporation, sputtering, and/or the like) and/or metal plating techniques (e.g., electroplating and/or electroless plating) can result in desirable surface finishes having average roughness values lower than the roughness values realizable in machined metal parts. For example, a roughness value for metal surfaces of the switchgear, including the conductive coating, is less than 10 micrometers. In some embodiments, the average roughness of metal surfaces of the green switchgear is less than 5 micrometers. In some embodiments, the average roughness of metal surfaces of the green switchgear is less than 2 micrometers. In some embodiments, the average roughness of metal surfaces of the green switchgear is less than 1 micrometer. In some embodiments, the average roughness of metal surfaces of the green switchgear is on the order of nanometers (e.g., "nanoscale"). Since the termination of the conductive paint (or other coating) at **315** in FIG. **3** has a smooth (or "rounded") profile, there is a reduced propensity for voltage breakdown, as discussed above. In some embodiments, the conductive paint **345** may be applied only to a portion of the silicon rubber cover or bushing boot, for example such that it only contacts a portion of vacuum interrupter **306**, or makes contact only with surfaces of the aluminum spacer **313**, avoiding the vacuum interrupter **306** altogether.

FIG. **4** shows a partial, cross-sectional detail view of a pushrod **411** according to some embodiments of the GREEN SWITCHGEAR. The pushrod is or has a moveable contact that actuates, generally along its longer axis, during switching operation (e.g., the selective "opening" and "closing," or "energizing" and "de-energizing" of a circuit) of the switchgear, and which penetrates the lower boot of the switchgear body in a manner such that the interface therebetween is continuously sealed via an inter-phase seal. As shown in FIG. **4**, the inter-phase seal is produced (e.g., at **418**) between finned silicone rubber connector **416**, which may, for example, be integrally formed with the lower boot **408** of the switchgear body (e.g., using a vulcanizing process), and solid insulating barriers (e.g., **417**) on the moving contact **411**. This inter-phase seal is formed by intimate contact between the finned silicone rubber connector **416** and the solid insulating barriers **417** (e.g., through press-fit attachment) such that a seal may be maintained during actuation of the pushrod. The space or gap defined between the solid barriers **417** may be referred to as a channel. In some embodiments, to affect a continuous seal between the pushrod and the lower boot, the finned connector **416** and the solid insulating barriers **417** extend fully around the periphery of the pushrod (e.g., having a shape that mirrors the cross-sectional shape of the pushrod). Although the fins of finned silicone rubber connector **416** are shown in FIG. **4** in such a way that they appear to penetrate or otherwise physically overlap with the solid insulating barriers (e.g., **417**) of the pushrod **411** that receives them, this is done to illustrate the interference fit (e.g., "press fit," or "friction fit") between the parts and is not meant to imply that the fins are required to encroach upon or pass through the solid insulating barriers (e.g., **417**) in which they are received. In some embodiments, the inter-phase seal is positioned between a high voltage portion (as represented by arrows **400**A of FIG. **4**) of the switchgear and a "grounded" or zero-potential portion (as represented by arrows **400**B of FIG. **4**) of the switchgear. In some embodiments, the inter-phase seal is positioned between a higher voltage portion and a lower-potential portion of the switchgear. Further embodiments of the inter-phase seal element of the GREEN SWITCHGEAR may include finned connectors employing five or more, or four or fewer, fins, and/or fins composed of any other suitable flexible insulator material. Such insulator materials may comprise silicone rubber and/or other suitable materials having suitable insulating, elasticity, flexibility and/or other relevant material properties either in combination with, or as a substitute for, silicone rubber. Examples include ethylene propylene diene monomer (EPDM) rubber, natural rubber, viton, nitrile butadiene rubber (NBR), and/or the like. Schematic drawings of an exemplary lower boot **1012**, including perspective and cross-sectional views, are shown in FIGS. **10**A through **10**F. A cross-sectional detail of finned connectors **1016** and **1026** comprising the inter-phase sealing mechanism according to some embodiments of the disclosure is shown in FIGS. **10**F and **10**G.

As explained above, helical grooves (for example as shown in FIGS. **5**A and **5**B at **519**, FIGS. **5**A and **5**C at **520**, FIG. **6** at **621** and **622**, or FIG. **7** at **722**) are provided in some embodiments of the GREEN SWITCHGEAR, and may advantageously serve as creepage paths for purposes of voltage sealing. The helical grooves may also advantageously provide thermal management, for example by directing or permitting cold air (as represented by white arrows **500**C in FIG. **5**A) to enter the switchgear body via the upper boot portion of the switchgear body at (see **520** of FIGS. **5**A and **722** of FIG. **7**) and/or directing or permitting hot air (as represented by dark arrows **500**B in FIG. **5**A) to escape the switchgear body via the bushing boot at **519**. By way of example, the direction of hot air travel in a helical groove is represented by arrow **500**A, and the direction of cold air travel in a helical groove is represented by arrow **500**D. In some embodiments, an interference fit (e.g., “press fit,” or “friction fit”) is made between the upper and lower boot, for example by stretching the upper boot and/or compressing the lower boot such that the upper boot accommodates a portion of the lower boot and securely attaches thereto once assembled. An interference fit may also be made between the bushing boot and the upper boot, and/or between the silicone rubber cover (e.g., FIG. **2** at **204**) and at least one of the bushing and the vacuum interrupter, in some embodiments. Although the helical grooves depicted in the drawings (for example as shown in FIGS. **5**A and **5**B at **519**, FIGS. **5**A and **5**C at **520**, FIG. **6** at **621** and **622**, or FIG. **7** at **722**) may in some instances appear to penetrate or otherwise physically overlap with the boot or boot portion that receives it, it is to be understood that this is done to illustrate the interference fit between the parts and does not mean that the grooves (or any portion thereof) are required to encroach upon, penetrate, or pass through the boot (or other component or portion thereof) in which it is received.

Alternatively, in some embodiments, the upper boot **505** and the lower boot **508**, as depicted in FIG. **5**A, can be understood to illustrate an “overlay” arrangement, where the upper boot has not yet been connected with the lower boot, and thus the upper boot perimeter has not yet been compressed to fit within the receiving portion of the lower boot, and/or the lower boot has not yet been stretched to accommodate attachment of the upper boot. Also, while FIG. **2** shows an interference fit between the silicone rubber cover and the bushing/vacuum interrupter (by virtue of their overlapping outlines), the components are shifted to the side in FIG. **3** so that the silicone rubber just touches the bushing and the vacuum interrupter, for illustrative purposes (e.g., to make the grooves more easily visible). It is to be understood that alternate configurations, for example, where the lower boot is stretched and/or the upper boot is compressed, or where the boots have a different spatial relationship with one another (e.g., “left” and “right” instead of “upper” and “lower”), are also within the scope of this disclosure.

FIG. **6** provides a detailed cross-sectional view of the helically-grooved regions of the bushing boot and the upper boot of an embodiment of the GREEN SWITCHGEAR, at **621** and **622**, respectively, in a “joined” or “joint” configuration, and with one of the inter-phase seals (at the location indicated by arrow **624**) not yet made. Although the finned silicone rubber connector depicted in the drawings (for example as shown in FIG. **4** at **416**, or in the lower left-hand portion of FIG. **6**) may in some instances appear to partially penetrate or otherwise physically overlap with the pushrod that receives it, this is done merely to illustrate the interference fit between the parts and does not imply that the fins (or any portion thereof) are required to encroach upon or pass through the pushrod (or other component or portion thereof) in which they are received. For example, while FIG. **4** (at **418**) and the left lower portion of FIG. **6** show an interference fit between the finned silicone rubber connector and the walls of the pushrod channel (by virtue of their overlapping outlines), the connector is shifted to the side (e.g., in a “disconnected” or “not yet connected” configuration) in the right lower portion of FIG. **6** for illustrative purposes (e.g., to make the fins more easily visible).

A detail partial view of the upper boot helical groove is found at **1220** of FIG. **12**B, along with a cross-sectional detail of conductive paint **1245** applied to the interior surface of said upper boot (with the paint extending from paint termination **1214** to paint termination **1215**), as used by some embodiments of the GREEN SWITCHGEAR. Notably, the cross-sectional profile of the paint reveals it to be at least somewhat conformal with the underlying bushing surface, and to have a curvilinear profile at paint termination **1214**. Depending on the embodiment, the conductive paint applied to the surfaces of the GREEN SWITCHGEAR may be substantially conformal, moderately conformal, somewhat conformal, or non-conformal, or may have a low degree of conformality. As described previously, the conductivity of the paint, shape of the painted profile, and/or location of the painted area help to avoid partial discharge caused by trapped air at the mating surfaces on primary current carrying components. Additionally, the curved ends of the paint may aid, for example, in reducing unwanted partial electrical discharge caused by field concentration at sharp points and edges. In some embodiments, flashing (e.g., thin layer(s) of material protruding from a part along the parting line of the cavity of the mould during manufacturing) is strictly forbidden on all surfaces of the bushing boot.

Schematic drawings, including multiple perspective views, of an upper boot **1127** and **1227** according to some embodiments of the GREEN SWITCHGEAR, are provided in FIGS. **11**A-**11**D and **12**A-**12**D, respectively. FIG. **12**A depicts a cross-sectional view of upper boot **1227**, taken along the line A-A indicated in FIG. **12**D. three-dimensional rendering of a bushing boot **803** according to an embodiment of the GREEN SWITCHGEAR, employing both a helical groove **819** as well as a series of heat removal fins **823** is shown in FIG. **8**, and FIGS. **13**A-**13**E are schematic drawings, including perspective, detail partial, and cross-sectional views, of a bushing boot **1303** according to some embodiments of the GREEN SWITCHGEAR. The heat removal fins (e.g., as also shown in FIG. **13**B at **1323**) may, in some embodiments, function as “heat sinks,” for example to conduct and/or radiate heat generated in the switchgear as a result of current passing through the unit (e.g., the heat forming a hot air cushion around the current carrying path). A partial detail view of helical groove **1319** is shown in FIG. **13**D. The silicone rubber according to some embodiments of the GREEN SWITCHGEAR may include an additive, such as iron-oxide, for example to improve the thermal conductivity without compromising its insulating properties. In some embodiments, flashing (e.g., the thin layer(s) of material protruding from a part along the parting line of the cavity of the mould during manufacturing) is strictly forbidden on all surfaces of the upper boot).

An example bushing boot **904** of the GREEN SWITCHGEAR is schematically shown in FIGS. **9**A through **9**E, via multiple perspective and cross-sectional views, as well as a cross-sectional detail of conductive paint **945** applied to the inner surface of said bushing boot **904**, as according to some embodiments of the GREEN SWITCHGEAR. Notably, the cross-sectional profile of the paint reveals it to be at least moderately conformal with the underlying bushing surface, and to have a curvilinear profile at paint terminations **914** and **915**. As described previously, the conductivity of the paint, shape of the painted profile, and/or location of the painted area help to avoid partial discharge caused by trapped air at the mating surfaces on primary current carrying components. Additionally, curvature at the ends of the painted region (e.g., by virtue of the shape of the paint layer itself, the shape of the paint in combination with an underlying surface, and/or the degree of conformality of a coating applied to the inner surface of the bushing boot **904**) can be configured to, for example, reduce unwanted partial electrical discharge caused by field concentration at sharp points and edges. In some embodiments, flashing (e.g., the thin layer(s) of material protruding from a part along the parting line of the cavity of the mould during manufacturing) is strictly forbidden on all surfaces of the bushing boot.

Once fabricated, embodiments of the GREEN SWITCHGEAR can be arrayed, co-located, grouped, interconnected, commonly housed, etc. as variously depicted in FIGS. **14**A through **14**D and FIGS. **15**A-**15**B. As shown in FIGS. **14**A through **14**D (with housing panels removed so that internal components are visible), an example of an assembled switchgear apparatus (collectively as **1450**) include high voltage cable **1428**, bushing boot 38 kV **1429**, silicone rubber insulation (e.g., at **1430**, **1436**), moulded pushrod **1431**, trip solenoid assembly **1432**, contact spring **1434**, vacuum interrupter **1433**, bushing **1435**, extension conductor **1437**, flexible conductor **1438**, close solenoid assembly **1439**, and plate return spring **1440**. GREEN SWITCHGEAR technology can be applied in applications such as reclosers, sectionalisers, load break switches, gas insulated switchgears (GIS), solid insulation switchgears (SIS), ring main units (RMU), switchfuse/fuseswitch combinations, busducts, vacuum circuit breakers (VCB) and/or in any type of switchgear panel. In some embodiments, close solenoid assembly **1439** is a recloser, and functions as a circuit breaker to selectively "open" and "close" one or more circuits internal to the switchgear Similarly, FIGS. **15**A-**15**B depict assembled switchgear apparatus (collectively as **1550**) with outer panels in place such that the internal components are not visible. Visible components in FIGS. **15**A-**15**B include high voltage cable **1528** and bushing boot 38 kV **1529**.

FIGS. **16**A through **16**D include multiple schematic views of an exemplary aluminum spacer **1613** according to some embodiments of the GREEN SWITCHGEAR. As can be seen, for example, in FIG. **3** at **313**, a spacer may be positioned between the vacuum interrupter and the primary bushing. In some embodiments, a spacer having a composition different from or in addition to aluminum. For example, in some implementations, the spacer comprises a relatively lightweight conductor material including, but not limited to, titanium, carbon, an aluminum alloy, a metal composite such as copper/aluminum, an electroceramic material, a carbon-nanotube impregnated material, a nanomaterial-impregnated material, a conductive polymer material, various combinations thereof, and/or the like. FIGS. **17**A through **17**D include multiple schematic views of an exemplary flexible guide **1744** according to some embodiments of the GREEN SWITCHGEAR, for example as can be seen in an assembled position in FIG. **1** at **144** or in FIG. **5**A at **544**. FIG. **17**C depicts a cross-sectional view of flexible guide **1744**, taken along line A-A indicated in FIG. **17**A.

FIGS. **18**A through **18**C depict multiple schematic views of an exemplary pushrod **1811** according to some embodiments of the GREEN SWITCHGEAR, for example as can be seen in FIG. **1** at **111** or FIG. **4** at **411**. As previously discussed, solid insulating barriers (e.g., as shown at **1817***a* and **1817***b*) on the pushrod may form a channel **1846**, for example to receive a finned silicone connector of a lower boot as hereinbefore described.

According to some embodiments of the disclosure, a switchgear apparatus includes a switchgear body housing having an upper boot and a lower boot (one or both of which comprise an insulating material), a vacuum interrupter with at least one stationary electrical contact and an insulating moveable contactor coupled to a moveable electrical contact, and two or more bushings having conductor material passing there through. In some implementations, the upper boot and the lower boot comprise an insulating material. Further implementations include one or more of the following: a bushing boot having at least one of a helical groove and/or an array of heat-removal fins; a flexible insulating cover enclosing at least a portion of the vacuum interrupter and an adjacent bushing; a helical groove in the upper boot; and/or a finned connector constrained within a channel in the pushrod. Embodiments can be configured to be free from (or essentially free from or substantially free from) harmful, toxic and/or dangerous gases, including environmental pollutants, such as greenhouse gases, and in some implementations, may be free, essentially free, or substantially free from sulphur hexafluoride.

According to some embodiments of the disclosure, a switchgear apparatus comprises a body housing having at least two insulating bushings, each bushing configured as at least one of a conduit and/or a support for an electrical conductor. The apparatus also comprises a vacuum interrupter coupled (directly or indirectly, depending on the implementation) to each of the at least two insulating bushings, the vacuum interrupter including one or more stationary electrical contacts and one or more moveable electrical contacts configured to selectively open and close an electrical circuit via one or more flexible conductor elements and/or one or more slidable electrical contacts. The apparatus also includes a pushrod (or like mechanism) coupled to at least one moveable electrical contact. Some embodiments may include a plurality of components forming a conductive path extending through the apparatus, wherein of the plurality of components are at least one of sealed, insulated and/or covered by a flexible insulating material and/or a rigid insulating material. In further embodiments, at least one of the insulating material, the bushing boot, and/or the insulating cover comprises a flexible dielectric material (which may be, by way of non-limiting example, silicone rubber, ethylene propylene diene monomer (EPDM) rubber, and/or the like. In some embodiments, the insulating material comprises a conductive coating on at least a portion of its inner surface and/or a conductive material embedded therein.

Some embodiments of the disclosure provide for a green switchgear apparatus that comprises: a switchgear body housing comprising an upper boot and a lower boot, the upper boot and the lower boot including an insulating material; a vacuum interrupter coupled at a first end to the upper boot and including an at least one stationary electrical contact and an at least one moveable electrical contact; at least one flexible conductor element housed within the switchgear body housing; a pushrod coupled to the at least one moveable electrical contact; at least one bushing boot coupled to the upper boot and having conductor material passing therethrough; at least one bushing coupled to the bushing boot; and at least one further bushing coupled to the vacuum interrupter at a second end of the vacuum interrupter and forming an interface therebetween, the interface surrounded by an insulating cover. In some such embodiments, the pushrod penetrates a wall of the lower boot, with the interface between the pushrod and the lower boot being sealed by cooperation between a perimeter groove of the pushrod and a complementary finned connector of the lower boot.

In some embodiments, a green switchgear apparatus according to the disclosure comprises: a switchgear body housing with an upper boot and a lower boot, the upper boot and the lower boot including an insulating material; a vacuum interrupter coupled at a first end to the upper boot and including an at least one stationary electrical contact and an at least one moveable electrical contact; at least one flexible conductor element housed within the switchgear body housing; a pushrod coupled to the at least one moveable electrical contact; at least one bushing coupled to the upper boot and having conductor material passing therethrough; at least one further bushing received by an insulating bushing boot, the bushing boot being coupled to the upper boot; and at least one bushing connected to the vacuum interrupter at a second end of the vacuum interrupter and forming an interface, the interface surrounded by an insulating cover. In some such embodiments, at least one of the upper boot and the lower boot comprises a perimeter groove configured to provide sufficient creepage distance such that at least one of flashover and/or voltage breakdown in the switchgear apparatus is prevented when in an energized condition. In some embodiments, the bushing boot comprises a perimeter helical groove, the helical groove configured to provide sufficient creepage distance to prevent at least one of flashover and voltage breakdown in the switchgear apparatus when in an energized condition. In some additional or alternative embodiments, the bushing boot comprises a plurality of heat removal fins, the fins configured to promote at least one of conduction and radiation of heat generated by the apparatus when in an energized condition. In some such implementations, the fins comprise an additive having thermal conductivity exceeding the thermal conductivity of a base material of the fins, the additive configured to promote heat transfer when in use. In some embodiments, at least one of the insulating material, the bushing boot, and/or the insulating cover comprises a flexible dielectric material, such as silicone rubber, EPDM rubber, and/or the like, either alone or in combination with another material, depending on the embodiment.

To address various issues and advance the art, the entirety of this application for GREEN SWITCHGEAR APPARATUSES, METHODS AND SYSTEMS (including the Cover Page, Title, Headings, Field, Background, Summary, Brief Description of the Drawings, Detailed Description, Claims, Abstract, Figures, Appendices, and otherwise) shows, by way of illustration, various embodiments in which the claimed innovations may be practiced. The advantages and features of the application are of a representative sample of embodiments only, and are not exhaustive and/or exclusive. They are presented only to assist in understanding and teach the invention. It should be understood that they are not representative of all claimed innovations. As such, certain aspects of the disclosure have not been discussed herein. That alternate embodiments may not have been presented for a specific portion of the innovations or that further undescribed alternate embodiments may be available for a portion is not to be considered a disclaimer of those alternate embodiments. It is to be understood that other embodiments may be utilized, and that functional, logical, operational, organizational, structural and/or topological modifications can be made without departing from the scope and/or spirit of the disclosure. As such, all examples and/or embodiments are deemed to be non-limiting throughout this disclosure. Also, no inference should be drawn regarding those embodiments discussed herein relative to those not discussed herein other than it is as such for purposes of reducing space and repetition. For instance, it is to be understood that the logical and/or topological structure of any combination of any components and/or any present feature sets as described in the figures and/or throughout are not limited to a fixed order and/or arrangement, but rather, any disclosed order is exemplary and all equivalents, regardless of order and/or arrangement, are contemplated by the disclosure. Furthermore, some of these embodiments can, where feasible, be combined to form additional embodiments, while other features may be mutually contradictory, in that they cannot be simultaneously present in a single embodiment. Similarly, some features are applicable to one aspect of the innovations, and inapplicable to others. In addition, the disclosure includes other innovations not presently claimed. Applicant reserves all rights in those presently unclaimed innovations including the right to claim such innovations, file additional applications, continuations, continuations in part, divisions, and/or the like thereof. As such, it should be understood that advantages, embodiments, examples, features, and functional, logical, operational, organizational, structural, topological, and/or other aspects of the disclosure are not to be considered limitations on the disclosure as defined by the claims or limitations on equivalents to the claims. It is to be understood that, depending on the particular needs and/or characteristics of a GREEN SWITCHGEAR individual user and/or enterprise user, various embodiments of the GREEN SWITCHGEAR may be implemented that enable a great deal of flexibility and customization. For example, aspects of the GREEN SWITCHGEAR can be scaled or otherwise adapted for any type of electrical power delivery project. While various embodiments and discussions of the GREEN SWITCHGEAR have been disclosed herein, it is to be understood that these embodiments may be readily configured and/or customized for a wide variety of other applications and/or implementations.

What is claimed is:

1. A switchgear apparatus comprising:

a switchgear body housing having an upper boot and a lower boot, the upper boot having an insulating material and the lower boot having an insulating material;

a vacuum interrupter having at least one stationary electrical contact and an insulating moveable contactor coupled to a moveable electrical contact; and

at least two bushings having conductor material passing therethrough,

the apparatus further comprising at least one of the following:

a bushing boot, separate from the upper boot and the lower boot, having at least one of a helical groove and/or an array of heat-removal fins;

a flexible insulating cover enclosing at least a portion of the vacuum interrupter and an adjacent bushing;

a helical groove in the upper boot; and

a finned connector constrained within a channel in the moveable contactor.

2. The apparatus of claim **1**, wherein the apparatus does not contain sulphur hexafluoride.

3. The apparatus according to claim **1**, further comprising a plurality of components forming a conductive path extending through the apparatus, the plurality of components being at least one of sealed, insulated and/or covered by a flexible insulating material or a rigid insulating material.

4. The apparatus according to claim **3**, wherein at least one of the insulating material, the bushing boot, or the insulating cover includes a flexible dielectric material.

5. The apparatus according to claim **4**, wherein the flexible dielectric material comprises silicone rubber.

6. The apparatus according to claim **4**, wherein the flexible dielectric material comprises ethylene propylene diene monomer (EPDM) rubber.

7. The apparatus according to claim **3**, wherein the insulating material includes a conductive coating on at least a portion of its inner surface and/or a conductive material embedded therein.

8. A switchgear apparatus comprising:

a switchgear body housing having an upper boot and a lower boot, the upper boot and the lower boot each including an insulating material;

a vacuum interrupter coupled at a first end to the upper boot and including an at least one stationary electrical contact and an at least one moveable electrical contact;

at least one flexible conductor element housed within the switchgear body housing;

a pushrod coupled to the at least one moveable electrical contact;

at least one bushing boot, separate from the upper boot and the lower boot, and having conductor material passing through the at least one bushing boot;

a first bushing coupled to the bushing boot; and

a second bushing coupled to a second end of the vacuum interrupter and forming an interface therebetween, the interface surrounded by an insulating cover.

9. The apparatus according to claim **8**, wherein the pushrod penetrates a wall of the lower boot, the interface between the pushrod and the lower boot being sealed by cooperation between a perimeter groove of the pushrod and a complementary finned connector of the lower boot.

10. A switchgear apparatus comprising:

a switchgear body housing comprising an upper boot and a lower boot, the upper boot and the lower boot each including an insulating material;

a vacuum interrupter coupled at a first end to the upper boot and including an at least one stationary electrical contact and an at least one moveable electrical contact;

at least one flexible conductor element housed within the switchgear body housing;

a pushrod coupled to the at least one moveable electrical contact;

a first bushing coupled to the upper boot and having conductor material passing therethrough;

a second bushing received by an insulating bushing boot that is separate from the upper boot and the lower boot; and

at least one bushing connected to a second end of the vacuum interrupter and forming an interface, the interface surrounded by an insulating cover.

11. The apparatus according to claim **10**, wherein at least one of the upper boot or the lower boot defines a perimeter groove, the perimeter groove defining a creepage distance sufficient to prevent at least one of flashover or voltage breakdown in the switchgear apparatus when in an energized condition.

12. The apparatus according to claim **10**, wherein the bushing boot defines a perimeter groove, the groove defining a creepage distance sufficient to prevent at least one of flashover or voltage breakdown in the switchgear apparatus when in an energized condition.

13. The apparatus according to claim **10**, wherein the bushing boot includes a plurality of heat removal fins configured to promote at least one of conduction or radiation of heat generated by the apparatus when in an energized condition.

14. The apparatus according to claim **13**, wherein the plurality of heat removal fins includes an additive whose thermal conductivity exceeds a thermal conductivity of a base material of the plurality of heat removal fins, the additive configured to promote heat transfer.

15. The apparatus according to claim **10**, wherein at least one of the insulating material, the bushing boot, or the insulating cover includes a flexible dielectric material.

16. The apparatus according to claim **15**, wherein the flexible dielectric material comprises silicone rubber.

17. The apparatus according to claim **15**, wherein the flexible dielectric material comprises ethylene propylene diene monomer (EPDM) rubber.

18. The apparatus according to claim **1**, wherein the bushing boot defines a perimeter groove, the perimeter groove defining a creepage distance sufficient to prevent at least one of flashover or voltage breakdown in the switchgear apparatus when in an energized condition.

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